Title:

Halliburton Drop Test Final Report

Authors:

Brian Worthen, Moad Abudia, Skylar Turner

Oklahoma State University

MAE 4344

Date:

Due: May 4, 2016

Introduction

Background

Surveying a design's viability with computer simulations before physical testing can save time and money. The goal of this project is to design and drop a skid similar to that of last semester's project and compare the results to a SolidWorks computational model. The intention is to develop an accurate finite element analysis computer model of the skid's structural integrity so that a subsequent physical tests will have higher success rates. In particular, points of high stress concentration are the main focus in order to determine whether the structure yields.

Computer simulations are used in order to model a system before being constructed. This allows high stress points to be explored and unviable designs to be eliminated. Through eliminating designs early in the process of design, testing, and redesign, costs can be reduced. The Halliburton drop test explores the use of SolidWorks to model skid designs.

The major limitations of simulations are accuracy and computational time. In order to improve upon and test these limitations, the project will attempt to test the validity of SolidWorks drop tests while simultaneously exploring methods to reduce simulation time through model simplifications. The next section will focus on the deliverables promised to the sponsor.

Deliverables

The following list details the deliverables expected to be provided by this project:

- Small scale skid frame - A small scale model of the skid is to be constructed in order to allow the group to independently conduct multiple drop tests as needed.
- A drop method - A method for conducting drop test trials must be designed in order to obtain data for comparison to the SolidWorks model.
- Strain gage/instrumentation configuration - Equipment must be selected and implemented in order to suit the needs of the physical drop experiment.
- SolidWorks 3-D Model - A three dimensional computer model of SolidWorks is to be designed, matching the drop parameters and dimensions of the small scale physical model.
- SolidWorks drop test data - Given drop parameters, the drop test tool within SolidWorks will be used to provide simulated results of a skid dropping onto a rigid, concrete surface. The strains and stresses of the skid are the desired results.
- Weight Attachment device - A weight attachment device for the physical model is expected to be designed. The mechanism will allow for the attachments of weights for drop tests in order to simulated a payload added to the skid.
- Physical drop test data - Using strain gages and a verified drop method, physical stress and strain results for the physical model dropping under established experiment parameters are to be acquired.

Detailed Description of Work Done:

The tasks conducted on this project can be separated into three separate zones: Computational modeling, skid construction, and testing. Computational modeling involved finding the most efficient manner of achieving accurate data and using these methods to model the physical test. Skid construction consisted of building a model, which resembles the previous year's design, within cost constraints. The testing involved data acquisition and developing a method which meets required safety standards.

Computational Modeling:

- Establish a 3-D model in SolidWorks
- Explore drop test settings
- Decide upon a configuration that best suits project needs
- Run a simulation and collect data

For the sake of data comparison between actual results and model predictions, a SolidWorks simulation was designed. This model provides the structure from which drop test simulation data will be gathered. Beginning with a number of different preliminary designs, the team finally settled on a general purpose structure, which also seemed to reduce the complexity of the physical model. This was critical in reducing computational time required for the FEA analysis.

A number of drop test simulations were surveyed, each with different mesh sizes, ranging from a 1.2 inch mesh down to a 0.4 inch mesh. The different tests were meant to reveal at which point the results of the simulated tests were converging, the error between the 0.6 in mesh and the 0.4 in mesh was 7.34% in measuring the maximum stress in the structure. As a result, a 0.4-inch mesh size was decided upon. Thereafter, the team was tasked to determine the time required for all sides of the structure to impact the ground. The purpose of this was to establish a simulation runtime length. One large mesh model was dropped in SolidWorks, and the stresses were calculated for a 0.1 second span, at which point it was determined that 0.1 second of simulated results were sufficient to conduct our analysis. Finally, a 0.4 in mesh model was simulated for 0.1 seconds after the impact.

Skid Construction:

- Designed a metal skid at a ½ ratio to the previous skid
- Selected steel as the material based on cost, strength, and similarity to previous work
- Purchased the metal and had the welding done at Stillwater Steel
- Designed a weight clamping mechanism

The initial design of the skid was primarily driven by Halliburton schematics and the project budget. By matching skid dimensions, a similar design to the actual structures used by Halliburton can be realized. A structure ratio of ½ allowed close matching of the tubing and dimensions while meeting budget constraints.

Figure 1 – Fabricated half-scale model of skid frame.

After finishing the skid, a clamping mechanism was designed in order to hold a variable load. The choice to add a weighted drop was to simulate the addition of a payload. Through weighting the skid, the data becomes more representative of actual use. The clamping mechanism was designed so that the connections would be rigid and that no modifications would be made to the skid. Drilling holes, welding, or any other process could compromise the structure. Furthermore, using a rigid connection allows for a more simplified computational model, which greatly decreases simulation processing time. A three dimensional model of the design is depicted by *Figure 2*.

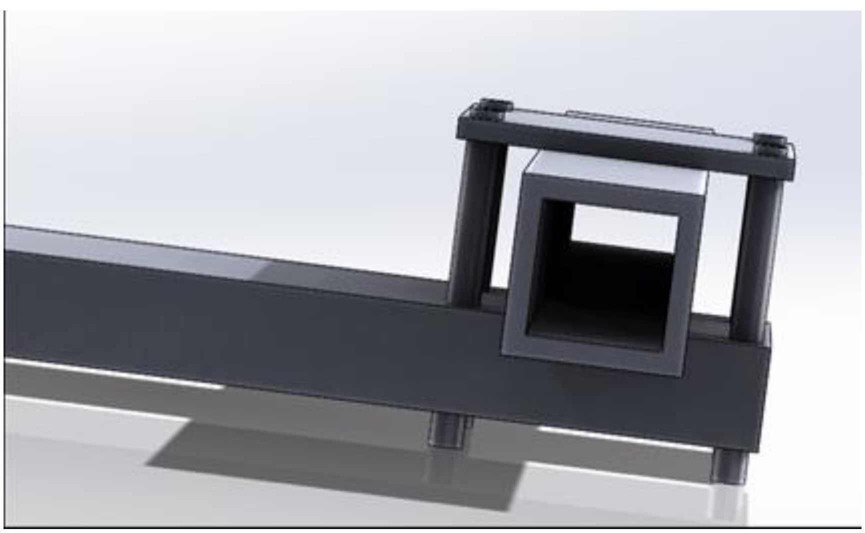


Figure 2 – SolidWorks design of weight attachment device

The skid was constructed and met the requirements from the initial design. The skid frame would act as the unweighted test model for data collection. While the clamping mechanism was not constructed due to time constraints, it could be used as a model for further projects involving weighted drops. A design for the clamping mechanism is shown later in the report.

Testing:

- Evaluated multiple drop test methods
- Selected a pin design and setup a pulley mechanism to lift the skid
- Used a DAQ-Strain Gage Reader to record signals from an Omega Strain gage
- Wired the strain gages to the skid
- Conducted tests and recorded data

While the drop test mechanism was being designed, a method of determining strain was developed. A standard strain gage reader setup was selected, as it allows direct reading of strain with a high sampling rate. The original design used single axis strain gages with four channels recording data, resulting in simultaneous data acquisition of four different positions in a single axis direction.

The original method was to use an Omega strain gage which connected to an Omega P-3500 strain reader that linked to an Omega recorder. The recorder was intended to send the acquired data to a laptop for data recording and processing. Several converters were needed to connect the recorder to a laptop, along with outdated software. Due to constraints on compatibility, the Omega recorder was never used.

A National Instruments (NI) Data Acquisition Device (DAQ) device was acquired and used in place of the Omega recorder. LabVIEW along with compatible drivers which came with the DAQ device. Due to having a single converter and a lack of multiple DAQ devices, one channel was used instead of the original four. This allowed data collection on a single strain gage. Strain gages were attached in four different positions according to the high points of stress determined by the computational model.

Several drop tests were performed, with three sets of data being accepted from each of the two highest stress concentration locations derived from the SolidWorks model. The drop tests were conducted using the correct five-degree angle orientation at a drop height of five inches. In correspondence to DNV test standards, the drop site was a flat concrete lot, which Mr. Gage allowed the group to use for the experiment. All protocols within the Standard Operating Procedures document were adhered to, and the drop tests were executed as planned.

The data received by the strain gages seemed inaccurate. Several zones yielded and the readings did not match the computational model. Calibration was not thoroughly conducted and issues occurred in the attachment of the gages. For example, several tests had to be repeated due to the conductivity of steel interfering with strain gage wiring. Furthermore, post processing methods of the signal received were not thoroughly conducted. Moreover, due to time constraints, the strain gages were not fully tested, which may have resulted in errors within the data.

Design Process

Schedule

Maintaining a set schedule was essential to completing project tasks. The Gantt chart below shows the entire schedule set for the project. A majority of the time was left for computational modeling and testing, as these can take large amounts of time. Computer model design was designated to be done immediately after the design of the physical model was accepted, incase redesign was needed. With the exception of the drop test, each preceding task on the chart was accomplished on time. The drop test schedule was moved to the “April 24-27” block after major delays in acquiring a strain gage reader.

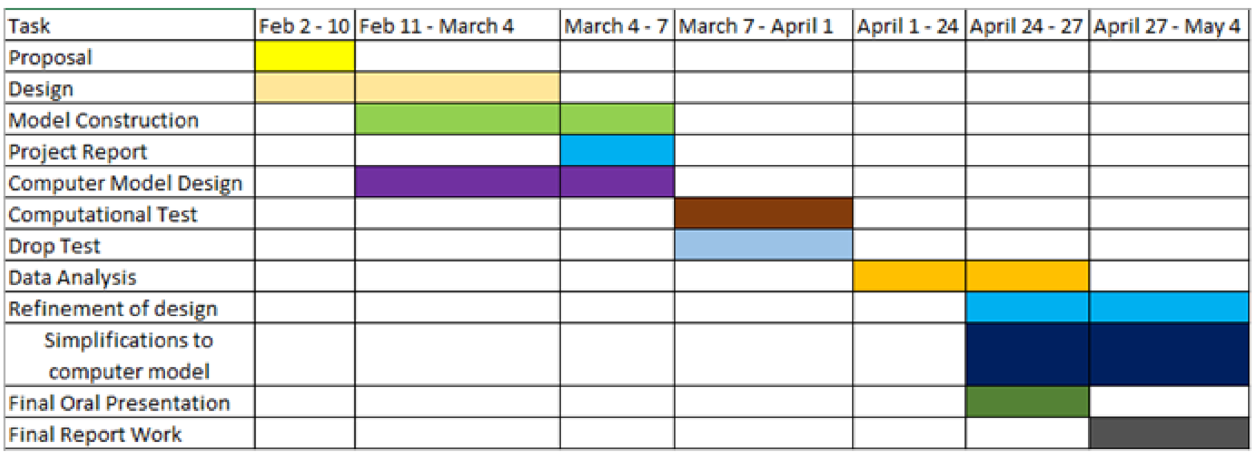


Figure 3 – Gantt chart provides overview of project schedule and tasks.

Establishing Drop Parameters

The following drop parameters were defined because the project was designed in order to determine whether SolidWorks could accurately model impact testing for a real world application. These drop parameters are used in the DNV certification process for skids that Halliburton uses.

Det Norske Veritas (DNV) is an autonomous and independent entity that provides classification, quality assurance, and certification of ships, facilities, and systems. Before a container can receive DNV certification, certain standards must be achieved. Listed below are parameters used for the vertical impact test certification:

4.6.4 Vertical impact test (pg. 32-33)

- The container must be dropped onto a concrete or rigid floor. This floor may be covered with a sheet of wood planks with a maximum thickness of 50 mm.
- The container must be inclined so that the lowest corner forms a minimum angle of 5° relative to the ground.
- The greatest height difference between the highest and lowest point on the container's bottom surface does not need to exceed 400 mm
- The impacting corner must possess the lowest rigidity.
- A minimum drop distance of 5 cm is to be performed
- An initial impact speed of at least 1 m/s is required

In order to pass the certification, no significant permanent damage is allowed. However, small cracks in welds and minor deformations may be repaired [1].

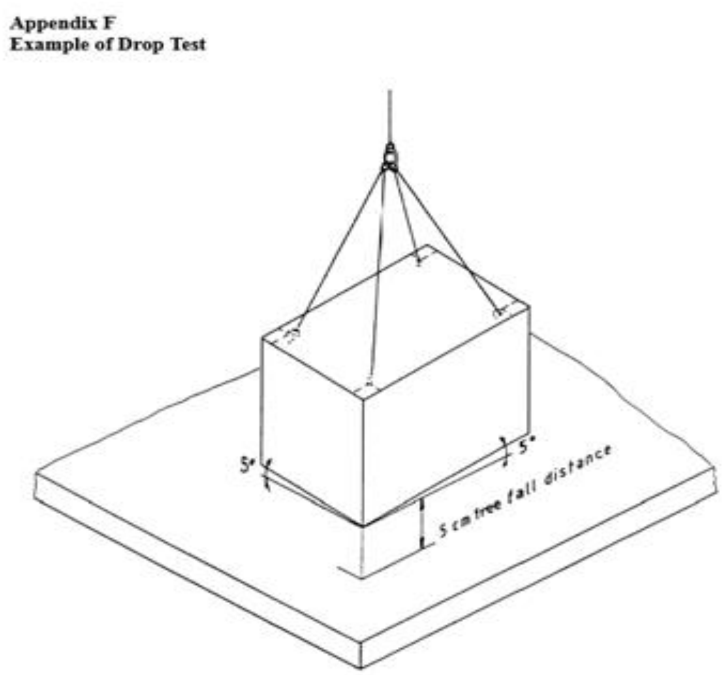


Figure 4 – Illustration of DNV drop test parameters as provided by the "Offshore Containers" standard for certification document.

Safety

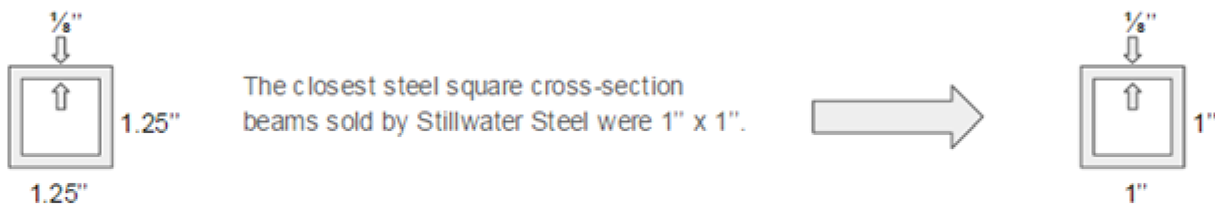
During the impact testing, personal protection equipment such as safety glasses and closed-toe shoes will be worn when necessary. In addition, personnel will be located away from the drop site prior to the test and during the drop. General situational awareness is expected at all times. Manufacturing tools and facilities will be required for the fabrication of the small scale drop test model. When using facilities such as the Design and Manufacturing Lab (DML), facility rules and procedures are to be followed at all times. Moreover, proper hearing and eye protection is to be worn, if necessary, when in the proximity of tools and machinery.

Initial Sponsor Meeting

Initially, two separate sponsor meetings were held near the beginning of the semester. One meeting was with Mr. Lake while the other was with two representatives from Halliburton. After these meetings, the project task and objective were refocused and defined as they are now when it became clear that Halliburton would be unable to sponsor the project. Thereafter, all advisement, communication, and mentorship would be done exclusively through MAE faculty.

Designing a small scale skid

A scaled down model was selected in order to allow the group to conveniently conduct multiple, on site drop tests as needed for the project. By referencing the schematics and bill of materials provided by Halliburton for the full scale skid, basic geometry was established for the small scale model. The frame size was reduced with thickness being the primary consideration. In order to achieve a standardized thickness, the original skid thickness of ¼’’ was reduced to ⅛’’ for the new design.



As a result, the constructed skid was designed to be a one-half scale model of the original Halliburton skid. Afterwards, steel members of the appropriate thickness were purchased and cut accordingly to satisfy the design. The steel cross sections were chosen to be square in correspondence to Halliburton skid schematics. Likewise, the frame was welded using straight welds in the interest of matching the full scale model. Lastly, the purchasing, cutting, and welding of the steel was done at Stillwater Steel to ensure professional quality.

The next page provides figures for both the 3-D model and the physical model for comparison.

Figure 5 – SolidWorks model of small scale skid with dimensions in inches.

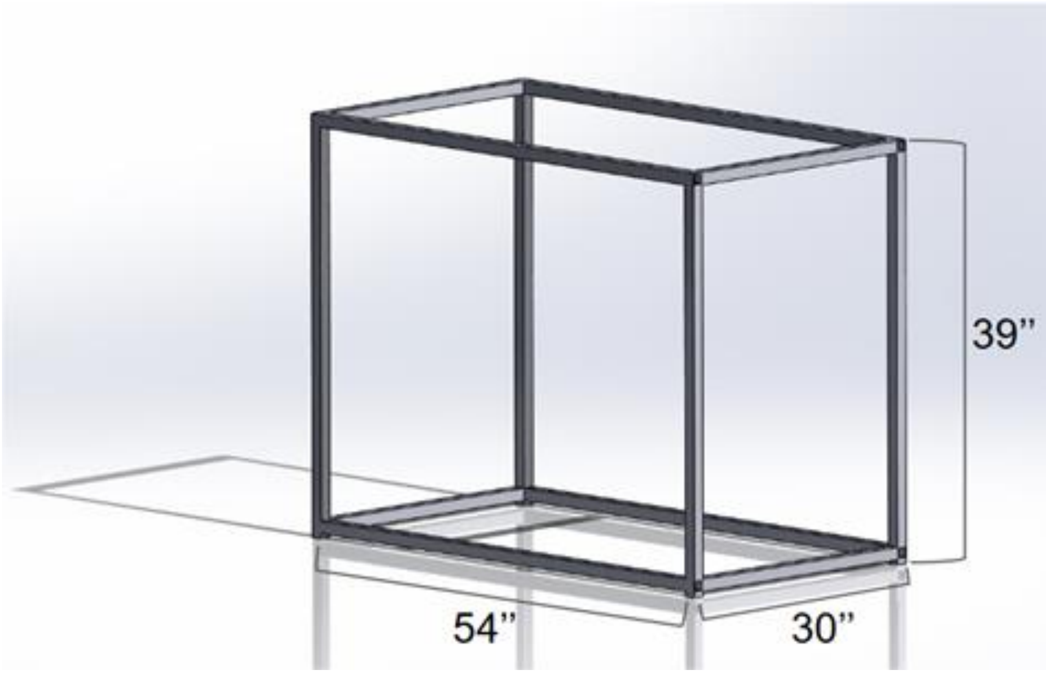


Figure 6 – Image shows actual fabricated skid model located at DML. Straight welds and dimensions match that of models shown in the previous figure.

Learning SolidWorks

To learn how to use solid works, one must learn the inputs and the initial conditions of the model. Listed below are settings which predominantly determine how the simulation operates.

<u>Parts</u>: the geometrical shapes that are being used in the simulation, and physical properties of each part.

<u>Connections</u>: the types of connections that bond parts of the model together, be it weldment, glues, etc.

<u>Mesh</u>: the size of the element that is used to approximate the behavior of the local segment.

<u>Set up</u>: determine the initial condition, orientation and target of the model.

As with any learning endeavor, challenges are often experienced, and solutions to those challenges must be identified. Long computational times were the most limiting resource when conducting simulations. Utilizing higher performance hardware at the DML provided faster simulation rendering. Moreover, uncertainty in the optimal mesh size was experienced early on in the project. By conducting six different simulations using different mesh sizes, the point of convergence was determined. This convergence of data from the simulation helped the group determine which mesh size was most suitable for the project's needs. However, the mesh size could not be set less than 0.4" in the single part model, but moving to an assembly model allowed SolidWorks to create finer meshes.

In regards to simulation run time, unweighted drop tests took eighty hours to simulated when using a .1 second runtime and 0.4-inch mesh size. On the other hand, using a weighted model provided inconclusive results in terms of simulation runtime requirements. After approaching the 100 hour mark, the SolidWorks simulation provided a prompt. The simulation never finished.

Clamping mechanism

In order to attach extra weight to the skid frame, a clamping mechanism was developed to create a rigid connection between a load carrying structure and the skid. A clamping mechanism was selected because the load carrying structure can be easily removed, and a clamping mechanism will not affect the structure of the skid. The load carrying structure will then be bolted to a weight which can be interchangeable. This will allow many different loads to be explored while testing the device.

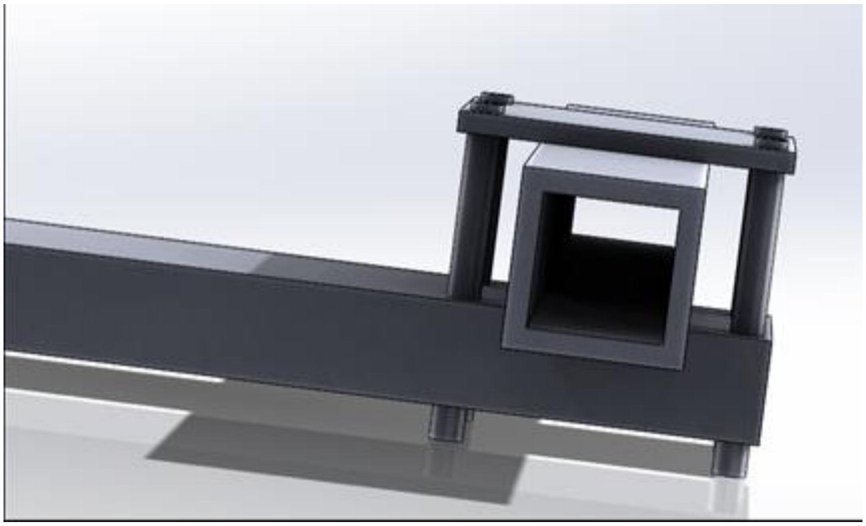


Figure 7 – SolidWorks rendering depicts clamping mechanism design for the skid weight attachments

Establishing a drop method

A pulley system was utilized to hoist the skid. While talking with Mr. Gage during the skid transportation to the DML, the group asked about using pulleys. From a safety standpoint, Mr. Gage did not object. Assuring the skid is suspended properly and can be released in a way that provides quality data is the primary focus at this point. Two methods for dropping the method were initially proposed: a trigger mechanism and a rope cutting release.

Initially, the method for releasing the skid was to melt Nichrome wire, which would cause the line supporting the skid to break and allow the skid to fall. However, the potential for whiplash created safety concerns. Moreover, the experiment would need to be entirely reset between drops after destroying the wire. Instead, a pin release mechanism was provided by Mr. Gage. Using a pin release greatly simplified the drop experiment design and set up. The primary concern was the ability of the pull pin to reliably release the skid upon being triggered. Four drops were done in order to test the effectiveness of the design. Ultimately, every test was successful, and the method was given the greenlight for testing once instrumentation was ready.

Figure 8 – DML set up for testing pin release function

After the pin release effectiveness was verified, the experiment procedure was established. Ultimately, the objective was to suspend and drop the properly instrumented skid from a height of 5 inches. In order to accomplish this, paracord rated up to at least 300 to 400 pounds was securely tied onto the top four corners of the skid frame. In total, approximately 30 feet of cord was used. The cord from each corner was attached to a steel ring rated up to 264 pounds. The ring was attached to the pin release mechanism, which was secured to the pulley system.

Thereafter, the skid was lifted by the pulley until the bottom portion of the skid frame was 5 inches from the concrete surface. Once personnel were confirmed to be safely positioned away from the drop site, the skid was released by pulling a cord attached to the release pin.

Strain Gages:

Initially, a strain gage setup was given by Dr. Conner for use on the project. The setup involved an Omega strain gage recorder and a p-3500 strain gage reader. This setup did not include compatible converters, a system to store and process data, or the gages themselves. A laptop was selected to be used for storage and data processing. A female to female 9 pin converter, along with a 9 pin to USB was acquired to transmit data.

Uniaxial strain gages were selected over rosettes due to the number of channels available, which was a maximum of four. Uniaxial strain gages were used in the previous project and were assumed to read the majority of the strain on the skid.

Due to software compatibility issues when using the Omega strain reader and issues with communicating with the device, an NI DAQ device was substituted for the Omega reader. The necessary drivers which ran through ChartView were not available. Usage of the DAQ device reduced the number of channels to one, due to lacking proper converters.

The strain gages were attached as shown previously on the basis of maximum and minimum stress loadings dictated by the computational model. They were attached in an adhesive-tape process. Originally, interference was encountered due to the conductivity of the steel. Several tests had to be repeated with insulation in order to gain better results. Despite our insulation efforts, the wires may have still experienced short-circuiting, creating error.

Final Design

SolidWorks

Using the stress results from the SolidWorks model, two high stress points were identified. The first is located above the impact corner, and the second is positioned across from the impact corner. High stress points are of imperative interest to the study, as they are the first points to yield, if such an outcome is to happen. As a result, strain gages were attached at these two critical locations.

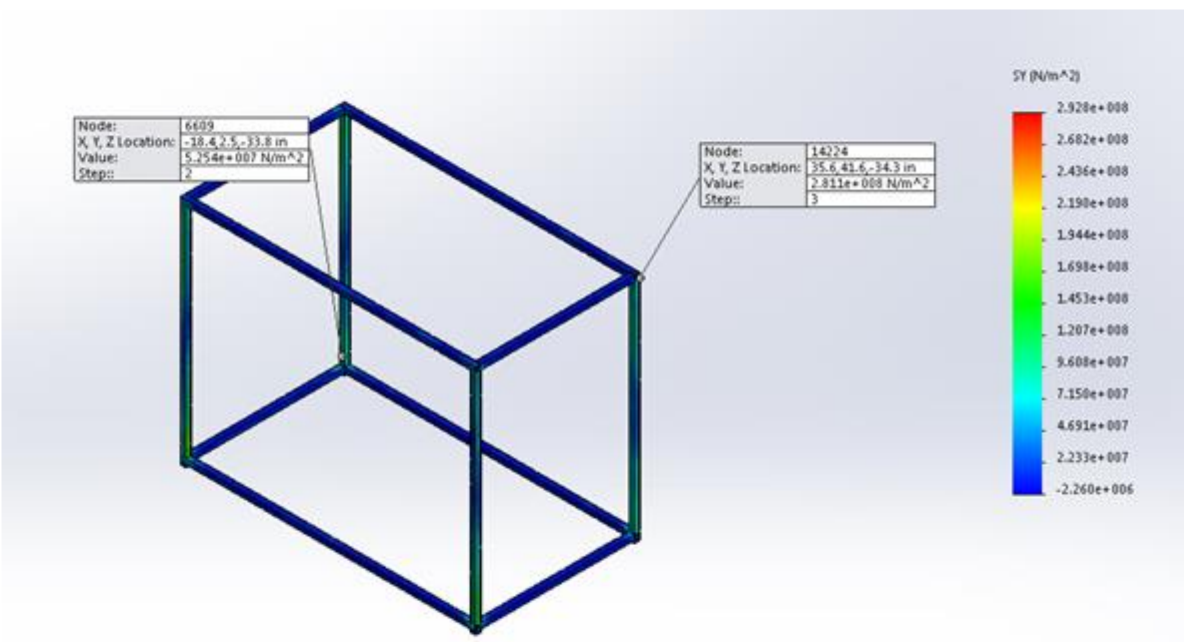
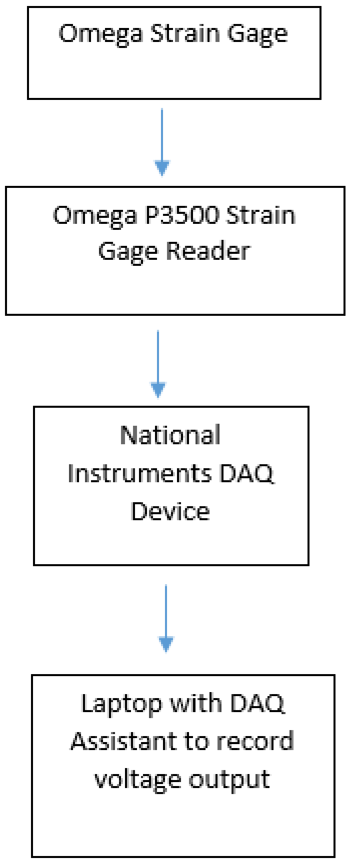


Figure 9 – The above image displays a SolidWorks depiction of high stress locations. Nodes correspond to strain gage positions 1 and 2.

Strain Gage Setup

As mentioned earlier, uniaxial strain gages were placed according to the computational models high stress zones. The process of attaching a strain gage involved: positioning the strain gage, applying tape to the gage to secure its position, partially removing the tape and applying adhesive, replacing the tape and allowing the adhesive to dry. Later, wires had to be insulted using tape so that the conductivity of the steel would not short the wire's voltage signals.

An Omega strain gage, Omega p3500 reader, NI DAQ acquisition device, and laptop were used to retrieve strain data. One channel was used to retrieve data; a drop could record data from a single location. The flowchart below demonstrates the signal processing method.



Drop Experiment Overview

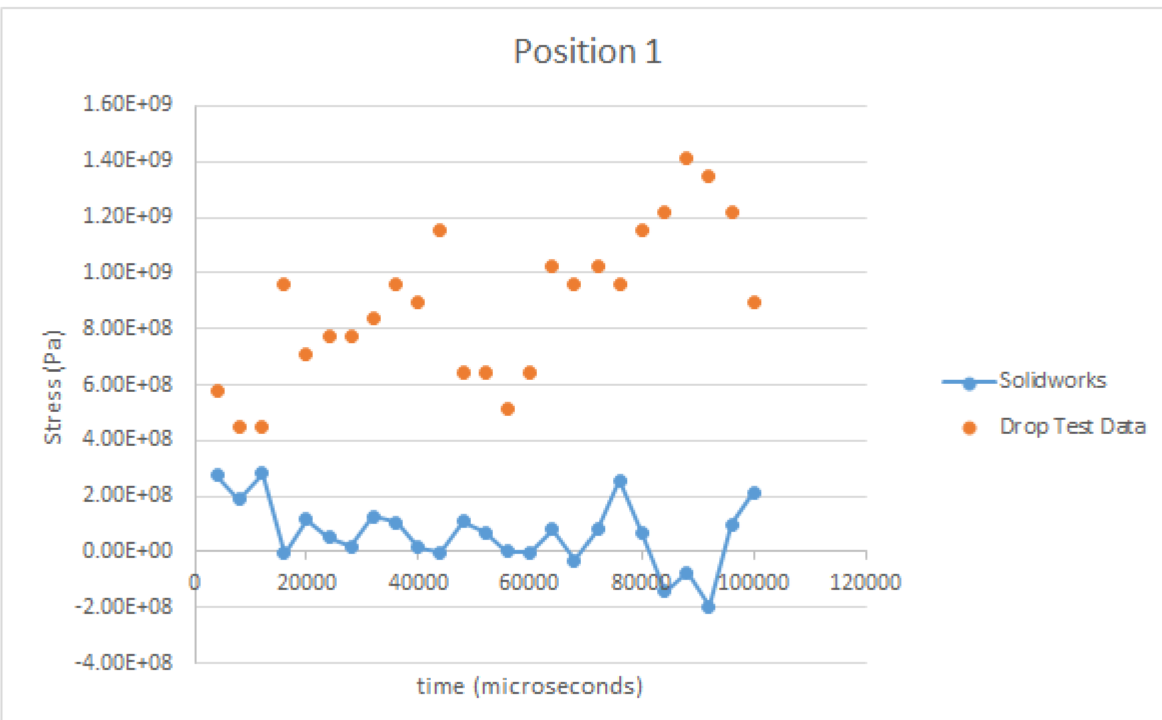
In order to satisfy DNV test standards, the drop site was a flat concrete lot, which Mr. Gage allowed the group to use for the experiment. In addition, the drop tests were conducted using the correct five-degree angle orientation at a drop height of five inches. Before hoisting the skid, instrumentation was placed at critical stress locations, which were identified using the SolidWorks model. Because the experiment was designed to test for yielding of the skid, only points of high stress were chosen.

Once the strain gages were attached, the skid was hoisted using a pulley provided by the DML. When the signal was given by the individual in charge of data recording, personnel distanced themselves from the skid and began a countdown. Thereafter, a cord was pulled to trigger the pin release mechanism, allowing the skid to fall onto the concrete surface. Several drop tests were performed, with three sets of data being accepted from each of the two highest stress concentration locations derived from the SolidWorks model. Before accepting a data set from a drop as a successful trial, instrumentation was verified to be functioning appropriately. Improper wiring and computer malfunctions resulted in the loss of relevant data during early test trials, so confirming the functionality of the recording device became a necessary routine.

Comparison of SolidWorks/Physical data

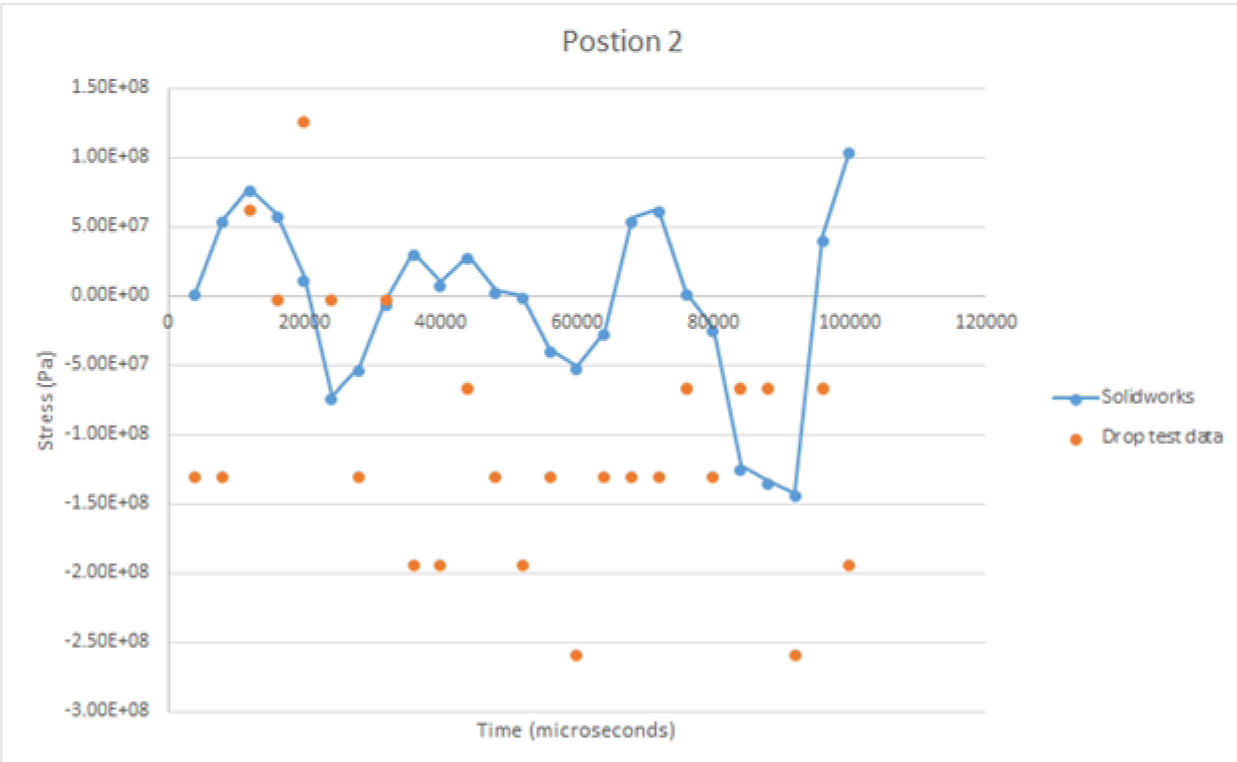
Results: Position 1

Figure 10 below illustrates the stress vs. time plots for both the SolidWorks simulation and the strain gage data at position 1. According to strain gage data, the skid yielded in tension.



Results: Position 2

Figure 11 below illustrates the stress vs. time plots for both the SolidWorks simulation and the strain gage data at position 2. According to strain gage data, the skid yielded in compression.



Evaluation of Design

The physical skid frame, drop method, 3-D model, SolidWorks simulation data, and strain gage configuration/instrumentation deliverables were each fully realized. However, instrumentation acquisition occurred too late in the process to allocate time for weighted drops and process improvement. As a result, the weight attachment design was designed but not fabricated as intended.

Furthermore, little room was made available for testing potential methods for improving the accuracy of the model. While data for the physical drop test was acquired, more analysis need to be done to validate it. More specifically, strain gages need to be tested to ensure that results are usable. In addition, more drop trials need to be performed using a greater number of strain gage locations.

Recommendations for Future Work

Strain Gages:

Strain gages were a necessity to the project, but were began late in the project partially due to equipment restraints on readers and recorders. Future work could involve testing the previously constructed skid and dedicating a larger portion of time to strain gage work. Future projects should use the National Instruments Data Acquisition device, as operation and setup was much simpler. Despite being simpler, these devices only have two ports for data acquisition. In order to attain better results, two DAQ devices need to be setup in the manner shown with the devices either running to separate computers, or the same computer on separate USB ports.

Two tests which could be conducted to calibrate strain gages and validate data. The first would be to use an attached known weight and measuring the strain through the gage, then performing hand calculations to validate the gage readings.

The second could be placing a gage on a tensile test device which can record the strain on its own sensor and matching gage data to the sensor. This setup can be performed in the OSU Metallurgy Laboratory. The benefits of this setup would be that if gages are not calibrated correctly, an adjustment factor can be made to match the gage to the tensile test data, making the gages usable. The primary issue with this setup is gaining access to the lab and that a gage would have to be destroyed in order to attain results.

Weighted Drops Tests:

Weighted drops could be conducted if accurate data was achieved through the gages. The weighted drops and computational models could be setup as described in the designs within this report. The major issue with weighted drops was the computational mode; the simulated drop test required an extremely large amount of time, and thus a method to reduce time on the test is needed. The SolidWorks model used for the weighted drop test is located in the appendix.

Budget Summary

The project budget for the project was split between two primary costs: the skid and strain gages. The table below shows the costs of each component. The primary costs in developing the skid were the welding and the steel.

Item	**Cost**
Project Budget	+$285
Skid Materials & Fabrication	-$220
Strain Gages	-$60
Remainder	**+$5**

As illustrated, the project met the expected budget, being $5 under. Several other small purchases were also made by members, such as tape and adhesive for strain gage attachment.

Appendices

References

[1] Det Norske Veritas, *Standard for Certification*, Offshore Containers, 2013, pp 32-33.

Calculations

Strain gage

S= ((4*E)/(GF*Vex))*Vo
S=stress
E= Modulus of elasticity= 2.1*10^11 Pa
GF= Gain factor =2.13
Vex= excitation voltage= 2.00 V
Vo= output voltage

Dimensioning of model

Length of steel required: 4 x 54'' = 18 ft, 4 x 39'' = 13 ft, 4 x 30' = 10 ft.
Total = 41 ft of steel.

Approximate weight: density = .289 lb_f/in^3 length = 492 in A_c= 2(⅛'')(1'') + 2(⅛'')(1'' - 2*⅛'') = 7/16 in^2
V= A_c x Length = 215.25 in^3

Weight = density x volume = 62 lb_f

Bill of Materials excerpt

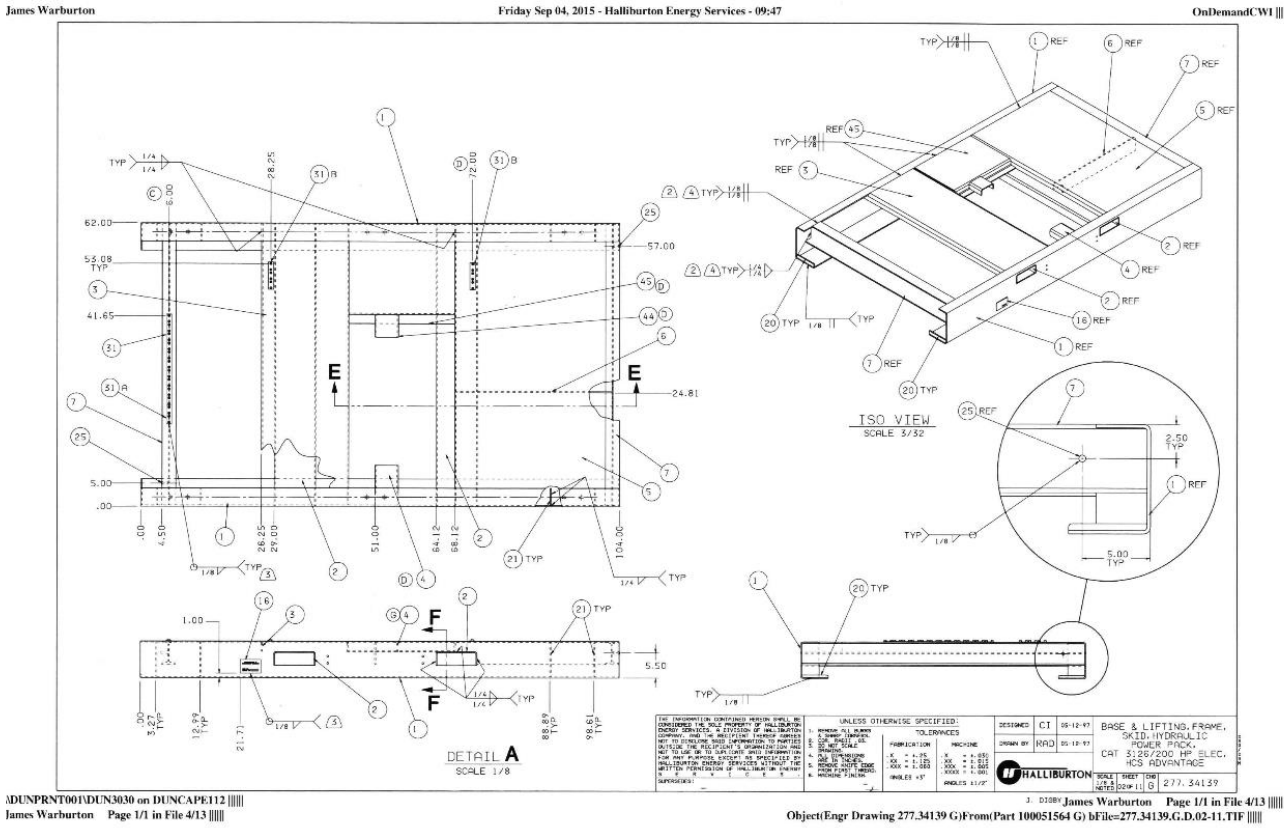
James Warburton **Friday Sep 04, 2015 - Halliburton Energy Services - 09:47** **OnDemandCWI |||||**

Production Release

Part Component List

Find#	Part/Mat'l#	Rev	Reference#	Drawing#	Qty#	Description	Est.Wt.	Dim A	Dim B	Dim C	TC
0001	100018787	I	52.53902		2.0	STEEL, PLATE, HOT ROLLED, ASME SA36, 0.250 INCH THICKNESS, PICKLED AND OILED, STANDARD SHEET SIZE 72 INCH WIDTH X 144 INCH LENGTH, SPECIFICATION 70.83258	0.07	104.0	17.05	-	BN
0002	100018787	I	52.53902		2.0	STEEL, PLATE, HOT ROLLED, ASME SA36, 0.250 INCH THICKNESS, PICKLED AND OILED, STANDARD SHEET SIZE 72 INCH WIDTH X 144 INCH LENGTH, SPECIFICATION 70.83258	0.07	63.0	14.05	-	BN
0003	100018787	I	52.53902		1.0	STEEL, PLATE, HOT ROLLED, ASME SA36, 0.250 INCH THICKNESS, PICKLED AND OILED, STANDARD SHEET SIZE 72 INCH WIDTH X 144 INCH LENGTH, SPECIFICATION 70.83258	0.07	61.5	22.55	-	BN
0004	100018787	I	52.53902		1.0	STEEL, PLATE, HOT ROLLED, ASME SA36, 0.250 INCH THICKNESS, PICKLED AND OILED, STANDARD SHEET SIZE 72 INCH WIDTH X 144 INCH LENGTH, SPECIFICATION 70.83258	0.07	8.75	11.3	-	BN
0005	100018787	I	52.53902		1.0	STEEL, PLATE, HOT ROLLED, ASME SA36, 0.250 INCH THICKNESS, PICKLED AND OILED, STANDARD SHEET SIZE 72 INCH WIDTH X 144 INCH LENGTH, SPECIFICATION 70.83258	0.07	61.5	34.64	-	BN
0006	100018787	I	52.53902		1.0	STEEL, PLATE, HOT ROLLED, ASME SA36, 0.250 INCH THICKNESS, PICKLED AND OILED, STANDARD SHEET SIZE 72 INCH WIDTH X 144 INCH LENGTH, SPECIFICATION 70.83258	0.07	34.02	4.75	-	BN
0007	100018391	F	52.02115		2.0	STEEL, BEAM, I, ASTM A36, 5.00 INCH SECTION DEPTH X 3.004 INCH FLANGE WIDTH X 0.326 INCH FLANGE THICKNESS X 0.214 INCH WEB THICKNESS, S5 X 10 POUNDS PER FOOT, UNS K02600, MATERIAL TEST REPORT REQUIRED, SPECIFICATION 70.94195	0.83	61.5	-	-	BY

PIR-100051564-G.doc Page 14 of 19 09/04/2015 09:46:37 AM lifting eyes -> Primary structure



SolidWorks Run Time Comparisons

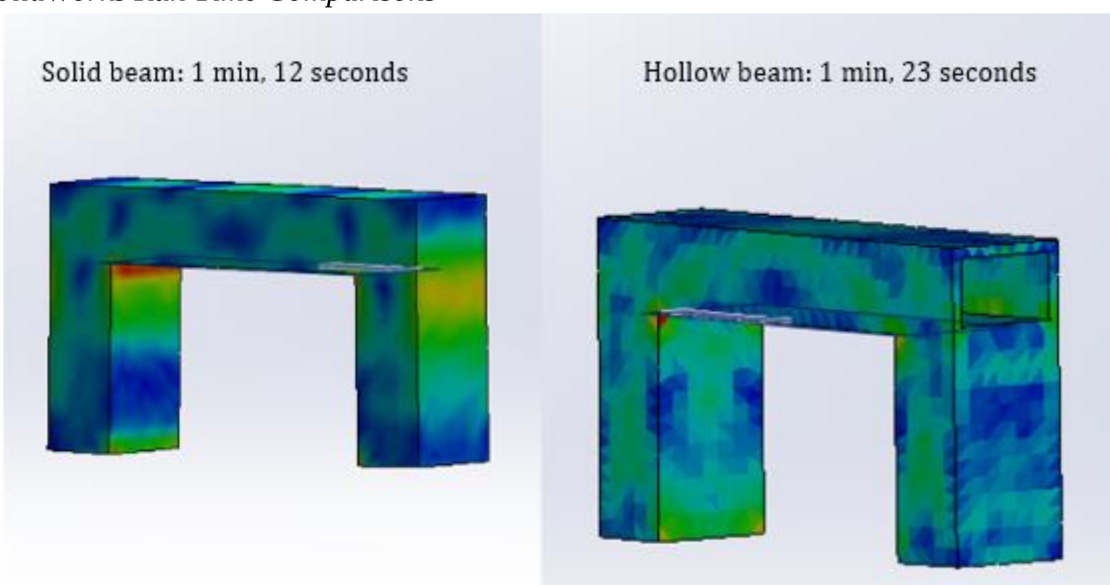


Figure 3 – Test images for basic comparisons of hollow and solid elements in SolidWorks FEA. Run times are listed for each corresponding object.

Standard Operating Procedure (S.O.P document) Excerpt

OKLAHOMA STATE UNIVERSITY
MAE STANDARD OPERATING PROCEDURE

This document is for use by the Project Team to develop a Standard Operating Procedure (SOP) and sent to the MAE Safety Review Board. **The completed SOP should be shared with all the members of the team.** The SOP should be revised whenever a significant change to the location or scope of work occurs. The MAE Safety Review Board (SRB) is available to assist in completion or review of the SOP. For questions, please call (405) 744-5915 or email john.t.gage@okstate.edu. Submit the completed SOP to the MAE SRB by emailing to maedml@okstate.edu with the subject heading: SOP. Please allow at least two business days for approval or requested revisions.

The following SOP generally follows under:

☐	SOP is for a general lab operation/process that could apply to several chemicals
☒	SOP is for a specific protocol/experiment/procedure
☐	SOP is for a specific chemical or class of chemicals with similar hazards

Section I.

Project Title:	Halliburton Drop Test		
Principal Investigator/Project Manager:	Dr. Delahoussaye	Department:	MAE
Email:	dela@okstate.edu	Phone:	405-744-5900
Project Duration:	Ends May 4, 2016		

Location of Fabrication/Testing Include room number(s) as appropriate

DML	DML Computer Lab	UAFS	
ATRC		Richmond Hills	
Other			

OSU Contact Person:		Phone:	
Local (Field) Contact Person:		Phone:	

Group/Project Members (Attach separate sheet of paper if necessary)

Name	Email	Team Leader	Team Member
Brian Worthen	brian.worthen@okstate.edu	☒	☐
Moad Abudia	abudia@okstate.edu	☐	☒
Skylar Turner	skylar.turner@okstate.edu	☐	☒
		☐	☐
		☐	☐

Section II.

Procedure Overview: Provide a brief description of the project and/or procedure.
(Attach separate sheet of paper if necessary)

Construct/Weld skid model (60-70 pounds unweight, up to 200 pounds fully weighted)
Unweighted drop trials will be performed first
Attach properly instrumented strain gages to skid frame
Fasten/tie cord to skid frame in order to hoist it
Secure fixed end of cord to a sturdy/rigid support
Use overhead crane to hoist the skid frame 5 inches from the ground
Pull pin release cord in order to drop skid onto concrete surface

Section III.

Hazards Inherent to the Project (Check all that Apply)

☐ Extreme Temperature	☐ Heights (roofs, lifts, towers, catwalks, etc.)
☐ Electrical Hazard > 50 volts or high current	☐ Potential for Oxygen Deficiency or Other Atmospheric Hazard (i.e. gas, vapor)
☐ Noise Generated > 85 dBA	☐ Storage of Hazardous Materials on site
☒ Sharp Edges	☐ Lithium Batteries
☒ Flying Debris or Impact	☐ Transportation of Hazardous Materials
☐ Pressure Vessel/Compressed Gas	☐ Other:_____
☐ Bungee Cables/Elastic Energy Storage	**Equipment Used**
☐ Fire Hazards (open flame, welding, cutting)	☐ Golf Cart/ATV
☐ Handling Hazardous Materials	☐ Riding Mower
☐ Dusts/Other Particulate Hazards	☐ Forklift
☐ Work in Confined Space (natural or man-made)	☐ Tractor
☒ Falling Objects	☐ Other _____
☐ Trenching/Excavating	
☐ Explosion	

Health and Safety Information: Briefly describe the hazards associated with the materials or equipment used during the procedure. (Attach separate sheet of paper if necessary)

Sharp edges on skid may be cutting/crushing hazard

Section IV.

Personal Protective Equipment or Clothing Required: All activities require basic protection including appropriate clothing, hand protection, safety shoes/boots, and eye protection. Any additional PPE requirements based on the hazards identified as part of minimizing risk of exposure, injury or illness. (Check all that Apply)

☒ Face Shields/Safety Glasses	☐ Respirator	☐ Emergency Shower
☐ Hearing Protection	Type:_____	☐ Extraction Equipment (Confined Space)
☐ Hard Hat	Cartridge/Filter Type: _____	☐ Other: _____
☒ Gloves	☐ N95 Particulate Mask	
☐ Fall Protection	☐ Portable Eye Wash	

Safety Training Required

☐ First Aid/CPR	☐ Laser Safety
☐ Emergency Action and Preparedness	☐ Forklift/Other Heavy Equipment
☐ Project Specific Hazard Communication	☐ N95 Particulate Mask Disclaimer
☐ Compressed Gasses	☐ Respiratory Protections
☐ HotWorks (Welding, Torch/Plasma Cutting)	☐ Other:_____
☐ Ladder	

Section V.

Method Procedures: Give a step-by-step instruction for the procedure. (Attach separate sheet of paper if necessary)

Firstly, prepare the properly instrumented skid to drop from 5 inches. In order to accomplish this, paracord rated up to atleast 300-400 pounds will be securely tied onto the top four corners of the skid frame. Several feet (approximately 20 ft.) of cord will be used in total. The cord from each corner will be attached to a steel ring rated up to 264 lb. The ring will be attached to the pin release mechanism which will be attached to the crane. Thereafter, the skid will be lifted by the overhead crane until the bottom portion of the skid frame is 5 inches from the concrete surface. Once personnel are confirmed to be safely away from the drop site, the skid will be released by pulling a cord attached to the release pin.

Mesh Size Comparison Data

1.3 in mesh size

	A	B	C	D	E	F	G	H	I	J	K	L
1	Date: 11:4	Friday	March 18	2016								
2	Model name:Part1											
3	Study name:Drop Test 1(-Default-)											
4	Plot type: Stress1											
5	Plot step: 25 time : 1135.99 Microseconds											
6	Result Type: von Mises											
7												
8												
9	Node	Value (N/	X (in)	Y (in)	Z (in)							
10	587	4.02E+07	1.25	41.02393	-0.4248		this point	40150000				
11	588	2.14E+07	2.5375	41.02393	-0.4248		max	1.71E+08				
12	589	5.50E+06	3.825	41.02393	-0.4248							
13	590	4.52E+06	5.1125	41.02393	-0.4248							
14	591	1.14E+07	6.4	41.02393	-0.4248							
15	592	1.20E+07	7.6875	41.02393	-0.4248							
16	593	9.79E+06	8.975	41.02393	-0.4248							
17	594	7.75E+06	10.2625	41.02393	-0.4248							
18	595	1.92E+07	11.55	41.02393	-0.4248							
19	596	1.62E+07	12.8375	41.02393	-0.4248							
20	597	3.18E+07	14.125	41.02393	-0.4248							
21	598	3.42E+07	15.4125	41.02393	-0.4248							
22	599	1.96E+07	16.7	41.02393	-0.4248							
23	600	1.93E+07	17.9875	41.02393	-0.4248							
24	601	3.88E+07	19.275	41.02393	-0.4248							
25	602	5.79E+07	20.5625	41.02393	-0.4248							
26	603	8.04E+07	21.85	41.02393	-0.4248							
27	604	8.83E+07	23.1375	41.02393	-0.4248							
28	605	1.11E+08	24.425	41.02393	-0.4248							
29	606	1.36E+08	25.7125	41.02393	-0.4248							
30	607	1.51E+08	27	41.02393	-0.4248							
31	608	1.43E+08	28.2875	41.02393	-0.4248							

1.1 inch mesh size

	A	B	C	D	E	F	G	H	I	J
1	Date: 11:4	Friday	March 18	2016						
2	Model name:Part1									
3	Study name:Drop Test 1(-Default-)									
4	Plot type: Stress1									
5	Plot step: 25 time : 1135.99 Microseconds									
6	Result Type: von Mises									
7										
8										
9	Node	Value (N/	X (in)	Y (in)	Z (in)					
10	702	3.14E+07	1.25	41.02393	-0.4248		this point	31410000		
11	703	1.22E+07	2.345745	41.02393	-0.4248		max	1.78E+08		
12	704	4.88E+06	3.441489	41.02393	-0.4248					
13	705	9.69E+06	4.537234	41.02393	-0.4248					
14	706	1.01E+07	5.632978	41.02393	-0.4248					
15	707	3.36E+06	6.728723	41.02393	-0.4248					
16	708	1.04E+07	7.824469	41.02393	-0.4248					
17	709	1.03E+07	8.920213	41.02393	-0.4248					
18	710	6.48E+06	10.01596	41.02393	-0.4248					
19	711	4.78E+06	11.1117	41.02393	-0.4248					
20	712	1.56E+07	12.20745	41.02393	-0.4248					
21	713	2.68E+07	13.30319	41.02393	-0.4248					
22	714	2.84E+07	14.39894	41.02393	-0.4248					
23	715	2.61E+07	15.49468	41.02393	-0.4248					
24	716	2.46E+07	16.59043	41.02393	-0.4248					
25	717	2.57E+07	17.68617	41.02393	-0.4248					

0.8-inch mesh size

	A	B	C	D	E	F	G	H
1	Date: 11:5	Friday	March 18	2016				
2	Model name:Part1							
3	Study name:Drop Test 1(-Default-)							
4	Plot type: Stress1							
5	Plot step: 25 time : 1136 Microseconds							
6	Result Type: von Mises							
7								
8								
9	Node	Value (N/	X (in)	Y (in)	Z (in)			
10	1480	8.25E+07	1.25	41.024	-0.4248		this point	82480000
11	1481	7.39E+06	2.0423	41.024	-0.4248		max	1.59E+08
12	1482	4.50E+06	2.8346	41.024	-0.4248			
13	1483	7.16E+06	3.6269	41.024	-0.4248			
14	1484	1.45E+07	4.4192	41.024	-0.4248			
15	1485	1.81E+07	5.2115	41.024	-0.4248			
16	1486	1.77E+07	6.0038	41.024	-0.4248			
17	1487	1.52E+07	6.7962	41.024	-0.4248			
18	1488	8.68E+06	7.5885	41.024	-0.4248			
19	1489	3.13E+06	8.3808	41.024	-0.4248			
20	1490	5.66E+06	9.1731	41.024	-0.4248			
21	1491	9.68E+06	9.9654	41.024	-0.4248			
22	1492	1.45E+07	10.758	41.024	-0.4248			
23	1493	3.36E+07	11.55	41.024	-0.4248			

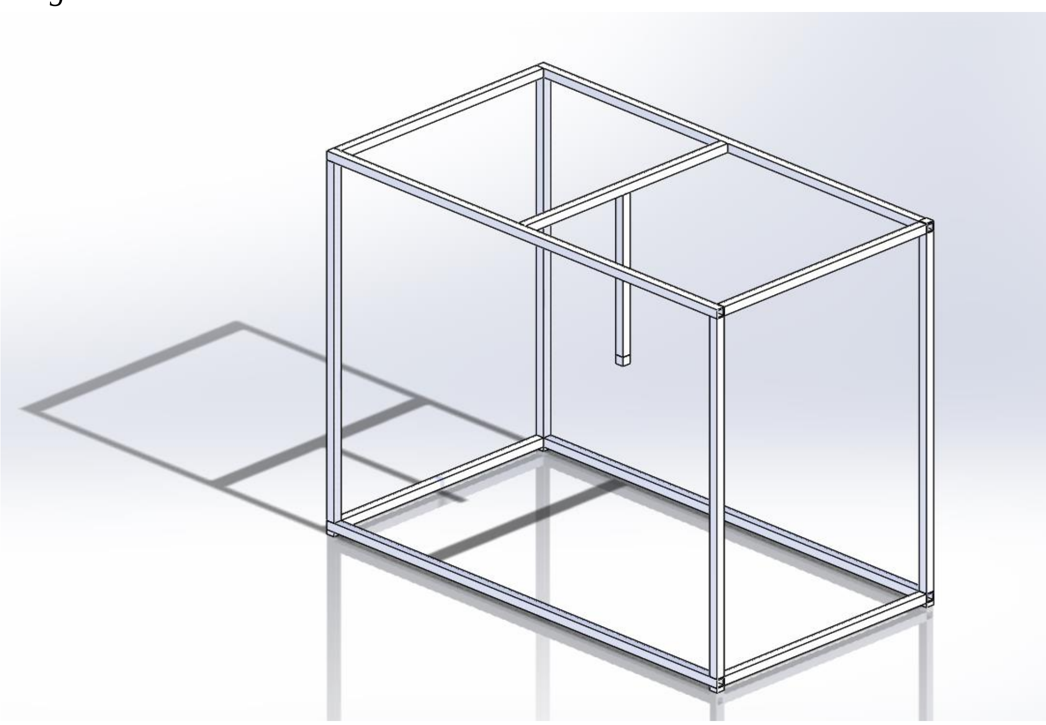
0.6-inch mesh size

	A	B	C	D	E	F	G	H
1	Date: 13:1	Friday	March 18	2016				
2	Model name:Part1							
3	Study name:Drop Test 1(-Default-)							
4	Plot type: Stress1							
5	Plot step: 25 time : 1135.97 Microseconds							
6	Result Type: von Mises							
7								
8								
9	Node	Value (N/	X (in)	Y (in)	Z (in)			
10	1971	9.91E+07	1.25	41.024	-0.4248		this point	99080000
11	1972	4.75E+07	1.8488	41.024	-0.4248		max	1.62E+08
12	1973	3.50E+07	2.4477	41.024	-0.4248			
13	1974	2.76E+07	3.0465	41.024	-0.4248			
14	1975	2.27E+07	3.6453	41.024	-0.4248			
15	1976	2.06E+07	4.2442	41.024	-0.4248			
16	1977	2.28E+07	4.843	41.024	-0.4248			
17	1978	2.49E+07	5.4419	41.024	-0.4248			
18	1979	2.82E+07	6.0407	41.024	-0.4248			
19	1980	2.96E+07	6.6395	41.024	-0.4248			
20	1981	2.32E+07	7.2384	41.024	-0.4248			

0.4-inch mesh size

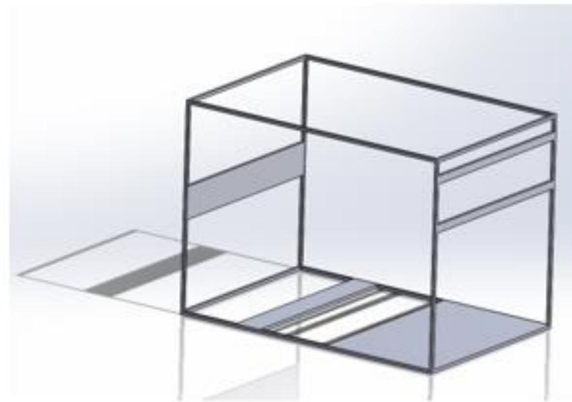
	A	B	C	D	E	F	G	H
1	Date: 13::	Friday	March 18	2016				
2	Model name:Part1							
3	Study name:Drop Test 1(-Default-)							
4	Plot type: Stress1							
5	Plot step: 25 time : 1135.96 Microseconds							
6	Result Type: von Mises							
7								
8								
9	Node	Value (N/	X (in)	Y (in)	Z (in)			
10	3976	1.71E+08	1.25	41.024	-0.4248		this point	1.71E+08
11	3977	8.34E+07	1.6492	41.024	-0.4248		max	1.74E+08
12	3978	4.85E+07	2.0484	41.024	-0.4248			
13	3979	3.75E+07	2.4477	41.024	-0.4248			
14	3980	2.98E+07	2.8469	41.024	-0.4248			
15	3981	2.65E+07	3.2461	41.024	-0.4248			
16	3982	2.23E+07	3.6453	41.024	-0.4248			
17	3983	2.16E+07	4.0446	41.024	-0.4248			
18	3984	2.53E+07	4.4438	41.024	-0.4248			
19	3985	2.92E+07	4.843	41.024	-0.4248			

Weighted Skid SolidWorks Model



Alternate Skid Model Considerations

Figure().suggested design with built in weight holding mechanism



Figure(). replica of phase 1 model

Early Strain Gage Considerations